

FIG. 4d shows a wet etch using hydrofluoric acid of windows 410 and 420 in PSG layer 119.

FIG. 4e shows deposition of aluminum film 430 (0.1–0.2  $\mu\text{m}$ ) as a high reflectivity layer.

FIG. 4f shows a wet etch (typically a mixture of phosphoric and nitric acid) Al to leave Al in mirror regions.

FIG. 4g shows etching of vias 133 to Si substrate 115 using  $\text{CF}_4/\text{O}_2$  RIE with a photoresist mask.

FIG. 4h shows the deposited polysilicon layer of 1–2  $\mu\text{m}$  thickness after being patterned to form hinge 155 for deflecting mirror 140. Patterning of polysilicon hinges 155 is described in Wu, "Micromachining for Optical and Optoelectronic Systems", Proceedings of IEEE, vol. 85, p.1833, 1997 and Pister et al., "Microfabricated hinges", Sensors and Actuators, A: Physica v 33 n 3 p. 249–256, 1992 which are hereby incorporated by reference in their entirety. If the RIE etching step is done before deposition of the polysilicon layer, the polysilicon can be deposited in etched recess 135 to reduce surface roughness due to the etching.

FIG. 4i shows the etch of PSG layer 119 and SCS layer 130 to pattern deflecting mirror 140, hinge 155 and access holes 137. Holes 137 allow for the etchant used to release deflecting mirror 140 to reach insulating layer 116. A typical size for holes 137 is 10  $\mu\text{m}$  by 10  $\mu\text{m}$ . Torsional mirror 150 is also defined in this step. Typical size for torsional mirror 150 in accordance with this invention is in the range of 1–2 mm square.

FIG. 4j shows the Ti—Au deposition of wettable metal bonding pads 111 and solder for solder bumps 110. Solder is reflowed into solder bumps 110 by heating at temperatures <310° C. This leaves the finished, unreleased MEMS parts, along with precisely defined recess 135, ready for the GaAs bonding step in FIG. 4.

FIG. 4k shows release of deflecting mirror 140 and hinge 155 by etching PSG layer 119 and insulator layer 116 by using a hydrofluoric (HF) based etch.

FIG. 4l shows placement of VCSEL 105 (thickness from 100–125  $\mu\text{m}$ ) into recess 135 for the GaAs bonding step. Solder bumps 110 can be defined on VCSEL 105 and VCSEL 105 is placed into recess 135 which approximately aligns the bumps to wettable metal bonding pads 111 and 113 due to the coordinated geometry of VCSEL 105, recess 135, wettable metal bonding pad 111 and solder bump 110 positions. Si Substrate 115 and VCSEL substrate 106 are heated to allow solder to flow and contact wettable metal bonding pads 113 on the bottom of VCSEL substrate 106.

FIG. 4m shows hinges 155, deflecting mirror 140, torsional mirror 150 and VCSEL 105 bonded to glass substrate 101 or to  $\text{SiN}_x$ -coated or  $\text{SiO}_2$ -coated Si substrate 101. Substrate 101 supports actuation electrodes 120 for torsional mirror 150.

FIG. 4n shows raised deflecting mirror 140 locked with latch 168. Angle of deflecting mirror 140 is fixed by the length of latch 168 and position of hole 165 at base of deflecting mirror 140.

Linear arrays of lasers can be bonded in a similar way; the extent of the array being perpendicular to the cross section shown in FIGS. 3a and 3b.

While the invention has been described in conjunction with specific embodiments, it is evident to those skilled in the art that many alternatives, modifications, and variations will be apparent in light of the foregoing description. Accordingly, the invention is intended to embrace all other such alternatives, modifications, and variations that fall within the spirit and scope of the appended claims.

What is claimed is:

1. An integrated laser beam scanning structure comprising:
  - a wafer having a recess on a side;
  - a layer having a first region and a second region, said layer being attached to said side of said wafer having said recess;
  - a deflecting mirror fashioned from said first region of said layer;
  - a torsional mirror fashioned from said second region of said layer, said torsional mirror having a first side; and
  - a semiconductor light emitter mounted in said recess whereby a light beam emitted from said semiconductor light emitter is deflected by said deflecting mirror onto said first side of said torsional mirror.
2. The structure of claim 1 wherein said wafer is a silicon on oxide wafer.
3. The structure of claim 1 wherein said layer is a single crystal silicon layer.
4. The structure of claim 1 wherein said semiconductor light emitter is mounted in said recess using solder bumps.
5. The structure of claim 1 wherein said semiconductor light emitter is a VCSEL chip.
6. The structure of claim 1 wherein said recess is deep reactive ion etched.
7. The structure of claim 1 wherein said torsional mirror is actuated by a pair of electrodes.
8. The structure of claim 1 wherein a ferromagnetic thin film is attached to said first side of said torsional mirror.
9. The structure of claim 8 wherein said torsional mirror is actuated by a thin film coil.
10. The structure of claim 1 wherein a thin film coil is attached to said first side of said torsional mirror.
11. A method for making an integrated laser beam scanner comprising the steps of:
  - providing a wafer having a recess on a side;
  - attaching a layer having a first region and a second region to said side of said wafer having said recess;
  - fashioning a deflecting mirror from said first region of said layer;
  - fashioning a torsional mirror from said second region of said layer, said torsional mirror having a first side; and
  - mounting a semiconductor light emitter in said recess such that a light beam emitted from said semiconductor light emitter is deflected by said deflecting mirror onto said first side of said torsional mirror.
12. The method of claim 11 wherein said wafer is a silicon on oxide wafer.
13. The method of claim 11 wherein said layer is a single crystalline silicon layer.
14. The method of claim 11 wherein said semiconductor light emitter is mounted in said recess using solder bumps.
15. The method of claim 11 wherein said semiconductor light emitter is a VCSEL chip.
16. The method of claim 11 wherein said recess is deep reactive ion etched.
17. The method of claim 11 wherein said torsional mirror is actuated by a pair of electrodes.
18. The method of claim 11 wherein said torsional mirror is actuated by a thin film coil and an external magnetic field.
19. The method of claim 11 wherein a ferromagnetic thin film is attached to said first side of said torsional mirror.
20. The method of claim 11 wherein a thin film coil is attached to said first side of said torsional mirror.

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